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RESEARCH ARTICLE

Performance of Energy Efficient S-MAC Protocol for Wireless Sensor Networks

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Abstract—Wireless Sensor Networks are often battery-powered, and hence extending the networking lifetime is one of the primary concerns in the ubiquitous deployment of wireless sensor networks. This paper introduces energy efficient MAC protocol used for wireless sensor networks. Energy consumption is the main problem in wireless sensor network. So minimize the energy consumption and make the life of sensor nodes. The S-MAC protocol is the solution. S-MAC protocol uses three technologies to minimize energy consumption and support self-configuration. The first, neighbouring nodes are synchronized to go to sleep periodically. Second, the synchronized neighbouring nodes make a virtual cluster to synchronize their wake-up and sleep periods so the control packet overhead is kept low. Third message passing is used to reduce contention latency and control overhead. In present work the cluster heads are formed, cluster heads was fixed and S-MAC protocol was simulated in NS-2 to study the performance in terms of network lifetime, energy consumption, cluster throughput, total power, and packet delivery ratio for cluster head.

Keywords— wireless sensor network, S-MAC protocol, energy consumption, periodic sleep scheduling, cluster throughput.

I. INTRODUCTION

Wireless Sensor Networks have become one of the flourishing research fields in recent years, as they are intended to have wide applications including environmental monitoring, smart spaces, medical systems, robotic exploration and many other fields [1]. Recent advances in micro-electro-mechanical system (MEMS) technology, wireless communications, and digital electronics have enabled the development of low-cost, low-power, multifunctional sensor nodes that are small in size and communicate undeterred in short distances. These tiny sensor nodes, which consist of sensing, data processing, and communicating components, leverage the idea of sensor networks based on collaborative effort of a large number of nodes. Sensor networks represent a significant improvement over traditional sensors, which are deployed in the following two ways [16]:

- Sensors can be positioned far from the actual, i.e., something known by sense perception. Large sensors that use some complex techniques to distinguish. The targets form environmental noises are required.

- Several sensors that perform only sensing can be deployed. The positions of the sensors and communications topology are carefully engineered. They transmit time series of the sensed phenomenon to the central nodes where computations are performed and data are fused.

For the WSN it is difficult to charge or replace the exhausted battery so other nodes objective is to maximize node lifetime. The broadcast characteristics of wireless channel is that, if any node in wireless networks sends wireless signals which will be listen by. If there are more than two nodes in the local area network which sends the signals, the signals may overlap this will result in collisions, and then the node which is waiting for receiving the signal will not receive data information correctly, resulting into more energy consumption. To solve these types of problem and introduces Medium Access Control (MAC) [16].

This paper presents sensor-MAC(S-MAC), a new MAC protocol designed explicitly for wireless sensor networks. While reducing energy consumption is the primary goal in our design. Our protocol also has good scalability and collision avoidance capability.

II. THE MAIN FACTORS THAT CAUSE ENERGY CONSUMPTION

To design an energy-efficient MAC protocol, some factors should be analysed that lead to energy consumption. Through a great deal of experiments and theoretical analysis, some factors that cause the energy consumption of sensor node summarized as follows:

A. Idle listening

Idle listening refers to the energy expanded by the nodes by having their circuits ON and ready to receive while there is no activity in the network [6]. This kind of listening can waste a great of energy, especially in WSN with low rate of data. This is particularly important in WSNs, as nodes use the channel sporadically. The idle listening problem in wireless networks can be minimized by putting the radio into sleep mode.

B. Collision

The collision occurs when two packets are transmitted at the same time. The packets can get corrupted and it may be required to be retransmitted. So a lot of time and energy gets wasted during this transmission and reception. Collisions should be avoided because of the extra energy wasted in frame retransmission.

C. Overhead

Energy is needed when sending, receiving or listening control packet. Because there is no transmitting data in the control packet only used to provide service for data information. Reduce the control message as much as possible on the basis that the data information can be transmitted normally. A MAC protocol should avoid and reduce the energy consumption caused.

D. Overhearing

The other problem is overhearing in which a sensor node may receive packets that are not intended for it. This node could have turned off its radio to save its energy. Overhearing is the energy consumed by the nodes by being constantly listening and decoding frames that are not meant for them. This is a consequence of using a shared media in which nodes do not know a priori whether the transmissions are for them or not [6].

III.RELATED WORK

A. S-MAC Protocol overview

S-MAC a contention based MAC protocol is modification of IEEE802.11 protocol specially designed for the wireless sensor network [7].

S-MAC (Sensor Medium Access Protocol), a clustering-based protocol that minimizes energy dissipation in sensor networks. The key features of S-MAC are:

- To conserve energy by avoiding overhearing in idle listening.
- To avoid collisions and to address the hidden terminal
- To fragment long packets into several frames and send them in burst. [2]

SMAC introduces a sleep scheduling algorithm that sensor nodes sleep for most of the time and wake up only to send data and to synchronize with networks. Thus, one S-MAC cycle time is divided into a sleeping period and a wakeup period. The wakeup period consists of SYNC period, RTS/CTS period, and data transmission period. In every SYNC period, sensor nodes broadcast a SYNC packet to neighbor nodes. Nodes also use the receiving SYNC packets to synchronize with neighbour nodes in the network.

The SYNC packet contains sender's next sleeping time which tells receiving nodes when the next transmission would take place for the next cycle. The RTS/CTS period is used to request for transmission and to response with a permission to transmit. Then, sensor nodes can send or receive data. The sleep schedule starts when sensor nodes are deployed to the workspace. Then every node keeps listening to the channel for a random time period from their neighboring nodes for a SYNC packet. If a sensor node does not receive any SYNC packet at the end of the period, it will generate a sleep schedule, and then broadcast the schedule within a SYNC packet [10]. Sensor nodes receiving a SYNC packet during the listening period will use the sleep schedule attached in the SYNC packet. The sleep schedule in S-MAC can reduce the network energy consumption by introducing a low duty cycle for each node. By using the sleep schedule, S-MAC can trade off the latency with the energy saving. [5]

B. Periodic Listen and Sleep

SMAC adopts the mechanism which allows nodes periodically go to sleep after a certain time of listening. Each node goes to sleep for some time and then begins to listen to the channel by a timer awaking it later. During sleep, the node turns off its radio, in this way, nodes can conserve some energy [9].

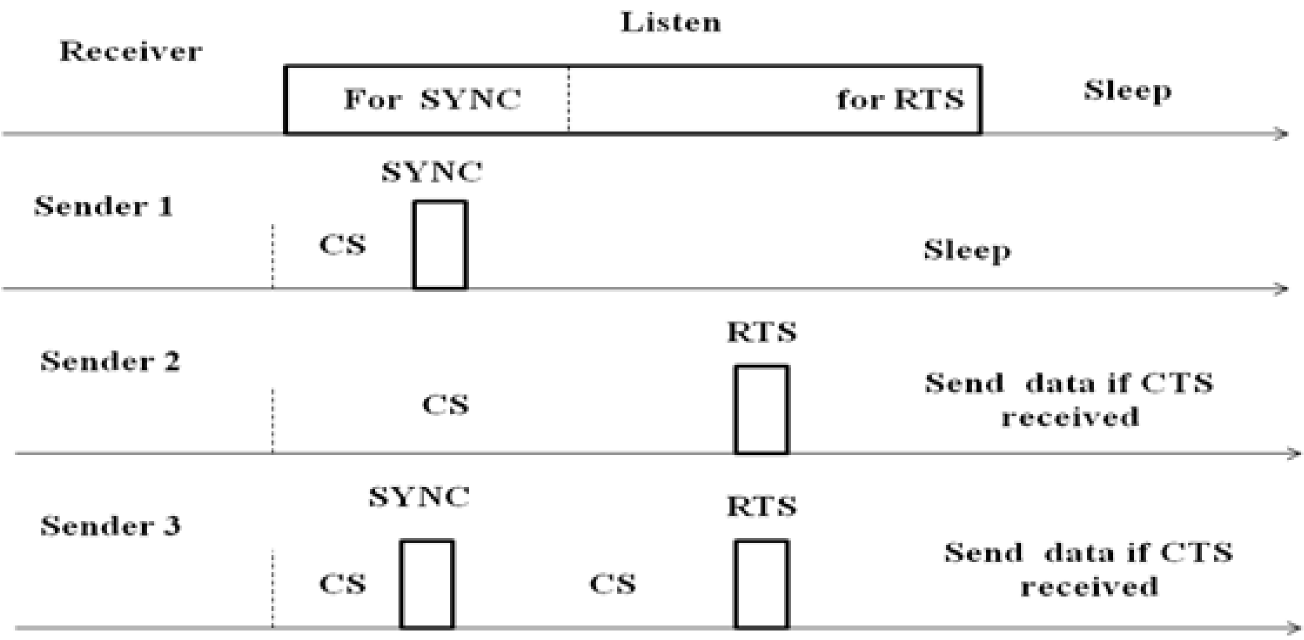

Fig. 1:- Timing relationship between a receiver and different senders

In many sensor network applications, if there is no sensing event, nodes will be in idle listening state for a long period of time. However, listening needs energy. In addition, suppose the fact that the data rate during this period is very low, keeping nodes listening all the time is unnecessary. In order to reduce energy consumption by idle listening, S-MAC adopts the mechanism which allows nodes periodically go to sleep after a certain time of listening. Each node goes to sleep for some time and then begins to listen to the channel by a timer awaking it later. During sleep, the node turns off its radio, in the way, nodes can conserve some energy.

A complete cycle of listen and sleep is called a frame. The listen interval is normally fixed according to physical-layer and MAC-layer parameters, the radio bandwidth and the contention window size, while the sleep interval in one application is different from another due to the different application requirements. All nodes can choose their own listen/sleep schedules. However, in S-MAC, neighboring nodes synchronize together to reduce control overhead. Synchronization is accomplished by periodically exchanging SYNC packets which includes the address of the sender and the time to its next sleep between neighboring nodes [9]. In S-MAC, each node maintains a schedule table that stores the schedules of all its known neighbors. The course of establishing the schedule table is as follows:

After a node starts working; it will listen for a fixed period of time. During that time, if it doesn't hear a schedule from its neighbors, it will choose its own schedule and start to follow it. Immediately after that, the node broadcasts a SYNC packet to announce the schedule. If during that fixed of time the node receives a schedule from a neighboring node, it will set its schedule to be the same [8].

IV. SIMULATION SETUP

To evaluate the performance of S-MAC protocol, different parameters were set in the network simulator NS-2 with incorporation of MIT uAMPS project (NS-2 Extension) sensor network framework [11]. It has the capability to simulate both wired and wireless environment.

A. Simulation Parameters

We have used terminal having configuration: Operating system Windows XP, Pentium IV processor, 512 RAM. We use NS-2.29 and Cygwin for simulation and AODV routing protocol [15].
Other simulation parameters are given below:

Table1:- Simulation Parameters

Parameters	Value
Number of Nodes	16
Topography Dimension	670m x 670m
Interface Queue type	DropTail/Pri Queue
Signal Propagation Model	Two ray ground
MAC Type	802.11 MAC Layer
Packet size	512 bytes
Mobility Model	Random Way point
Antenna Type	Omni Directional
Mobile Routing Protocol	AODV
Channel	Wireless Channel
Link Layer Type	LL
Network Interface Type	Wireless phy

V. SIMULATION RESULTS

Following performance metrics were targeted in the simulation results:

A. Network Lifetime

The network lifetime [17] depends on the application and is given by different ways. The proposals consider the time of death of first node or the death of 50% nodes of the total nodes or when number of alive nodes is less than the desired number of cluster head, at any round (death of 96%). In this paper, the results are presented for all three scenarios.

B. Cluster Throughput

The network throughput is defined as the total number of packets delivered at the sink node per time unit [4].

C. Packet Delivery Ratio

Packet delivery ratio is the fraction of packets sent by the application that are received by the receiver and is calculated by dividing the number of packets received by the destination through the number of packets originated by the application layer of the source.

D. Energy Consumption per bit

The energy efficiency of the sensor nodes can be defined as the total energy consumed / total bits transmitted. The unit of energy efficiency is joules/bit. The lesser the number, the better is the efficiency of a protocol in transmitting the information in the network. This performance matrices gets affected by all the major sources of energy waste in wireless sensor network such as idle listening, collisions, control packet overhead and overhearing [4].

VI. RESULTS

Graph given below, shows the results of energy consumption with respect to simulation time.

There are total numbers of node 16 and the amount of initial energy is 150 joules. It is shown in graph at simulation time 1.0 mille seconds; energy consumption is approximately 150 joules. As time passes energy consumption is decreased, at time 3.5 mille seconds, energy consumption is 100 joules. There is decrement in energy consumption and increment simulation time. Similarly at simulation time 4.0 mille seconds, energy consumption is 92 joules. After 4 mille seconds, energy consumption is 37 joules. Finally at simulation time 10 mille seconds and energy consumption is 10 joules. At last we can say that if simulation time is increased then energy consumption is decreased. Initially there was 150 joules of energy and at last we have 10 joules.

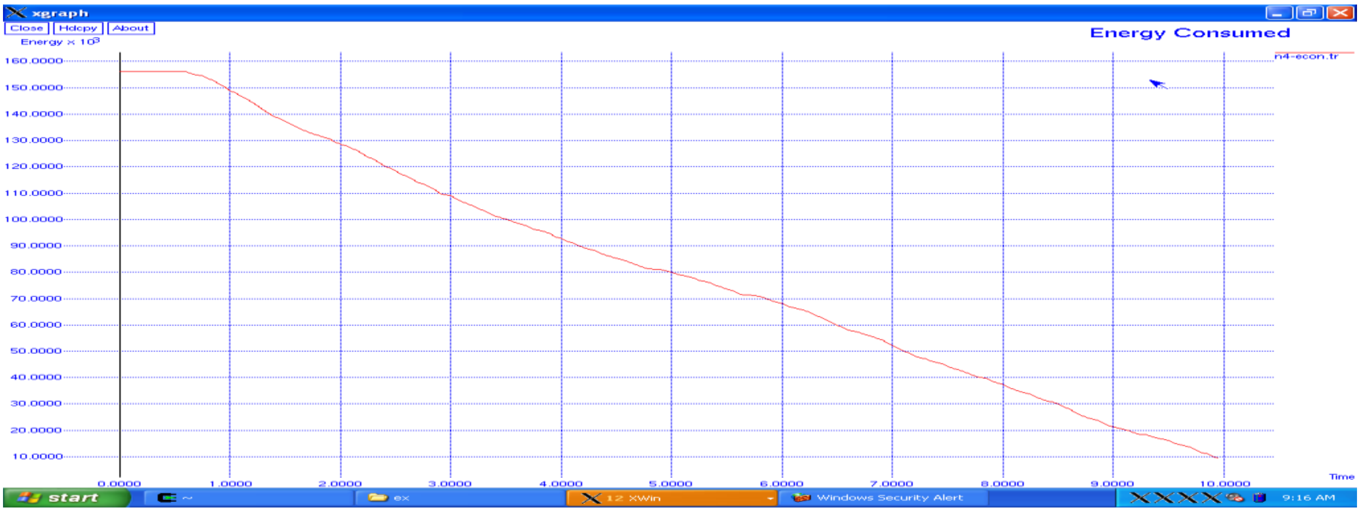

Fig.2. Energy Consumption Vs Simulation Time

The Fig.3 shows the results of cluster throughput, number of packets either send or received with respect to simulation time. There are total numbers of node 16 and the amount of initial energy is 150 joules. It is shown in graph that as the simulation time is increased, cluster throughput is also increased. At simulation time 0.5 mille seconds, cluster throughput or numbers of packets are zero. After 0.5 mille seconds, cluster throughput is 22 packets. Similarly at simulation time 2.0 mille seconds, numbers of packets are 76. Gradually as simulate time is increased, cluster throughput is also increased. Now at simulation time 3.5 mille seconds, cluster throughput is 144 packets. In last when simulation time is 4.5 mille seconds then number of packets are 191. Finally at simulation time 5 mille seconds and cluster throughput is 218 packets. So it is shown in table that if simulation time is increased than cluster throughput is also increased. Here the graph shows the linear line with respect to simulation time and number of packets send and received.

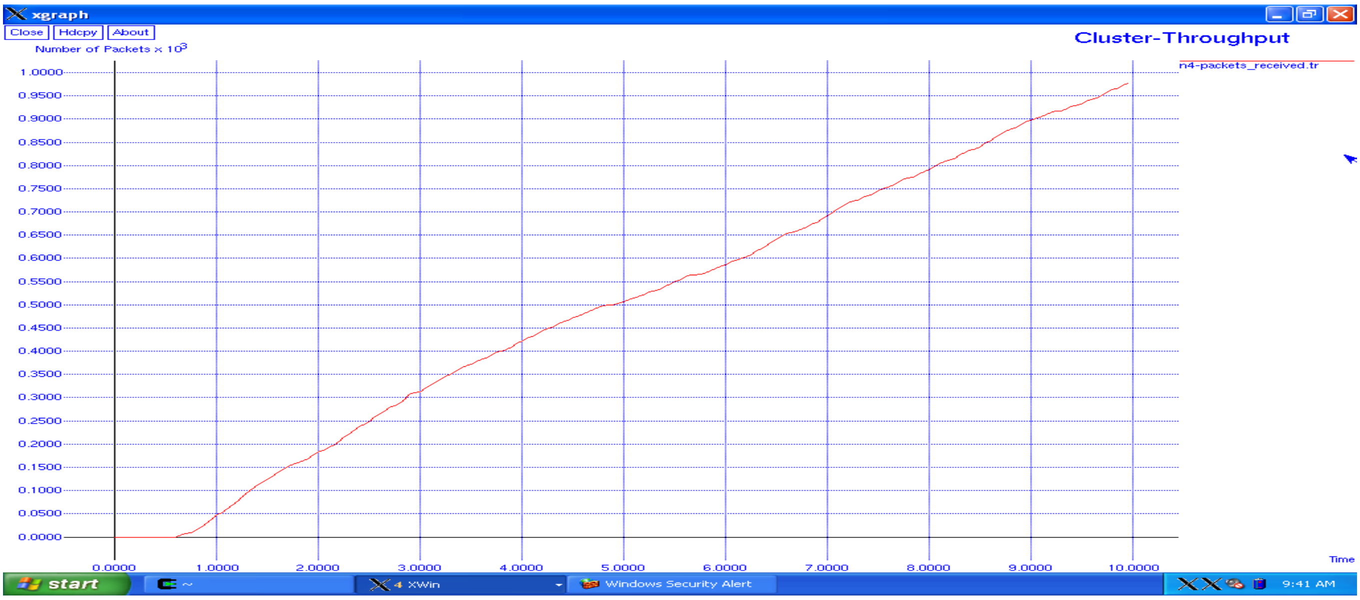

Fig.3. Number of Packets Vs Simulation Time

VII. CONCLUSIONS

In this paper the effect of cluster head formation simulated in S-MAC protocol. In this work energy consumption, total power, cluster throughput, and packet delivery ration is implemented. It is proved that energy consumption is reduced and also increase the network lifetime of the wireless sensor network. It also increases the total power and packet data ratio. It is shown that the S-MAC protocol using sleep scheduling algorithm offers a better solution to energy efficiency usage in a wireless sensor network.

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